— SECTION B —

CHEMICAL SCIENCES

Contents

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MOLECULAR WEIGHTS FROM MICRO QUANTITIES OF MATERIALS[1]

By I. E. Puddington

Abstract

A method is proposed for the determination of the molecular weight of chemical compounds in which the unknown substance may be used successfully in quantities of 1 mgm. or less. The method depends on the accurate measurement of the difference in vapor pressure between a solution of the unknown compound and the pure solvent, and this is accomplished with a modified mercury U-tube manometer. The results presented indicate that the difference between the experimental and theoretical molecular weights is of the order of 2%. Determinations require from two to three hours and the sample may be recovered.

Introduction

The work of Frazer and others (1, 2) in the few years following 1914 showed that static measurements of the vapor pressure of pure solvents and solutions could be made with considerable precision. Their work also showed that the vapor pressure of solutions of several nonionizing chemical compounds could be predicted by Raoult's law, even at quite high solute concentrations. However, this method of approach has not become popular for the estimation of molecular weights, despite the obvious advantage that vapor pressures can be measured over a range of temperature and are not subject to superheating and undercooling effects. The possibility of this method being used where only small quantities of material are available has prompted the present investigation.

At low molecular concentrations Raoult's law may be written in the form

$$m = w \cdot \frac{M}{W} \cdot \frac{P}{P - P_0},$$

where m and w are the molecular weight and mass of solute present, M and W are the molecular weight and mass of the solvent used, while P and P_0 are the vapor pressures of the solvent and solution measured at the same temperature. In the determination of molecular weights P and $P - P_0$ are the quantities observed. P is normally large enough to be measured directly with an ordinary mercury manometer, but since $P - P_0$ is the difference between two relatively large quantities, it is preferable to measure this difference by a sensitive differential method rather than attempt to measure P and P_0

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absolutely to the required degree of precision. The pressure differential, $P - P_0$, can be increased by working at elevated temperatures or by using solvents with high vapor pressures. These restrictions frequently lead to other difficulties, however, and the work reported here has been done a few degrees below room temperature, using solvents with relatively low vapor pressures.

Experimental

The apparatus, which is similar to one used in previous investigations, where its operation was described (4, 5) is shown in Fig. 1. Linear displacement of a mercury thread in the uniform capillary A indicates pressure changes at the
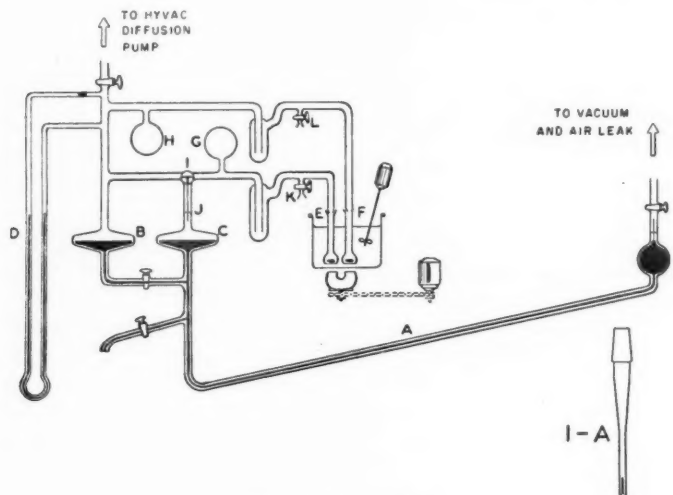
FIG. 1. *Apparatus.*

enlargements in the U-tube mercury manometer, B and C, with a magnification of 1650. Since the mean value of a group of readings on A can be reproduced to within $\pm$ 1 mm., values of actual vapor pressure differences between solvent and solution which are impressed at B and C should be good to about 0.001 mm. The vapor pressure of the pure solvent is recorded on the manometer D. Solution and solvent are contained in the sample holders E and F, which are partially immersed in a thermostat.

In the initial work on the problem, solutions were made up gravimetrically and about 0.5 cc. of solvent and solution placed in their respective sample holders. Both samples were then freed from air by vacuum distilling the solvent to the traps and back to the sample holders several times, using a suitable refrigerant to prevent loss of solvent. The pressure in the system was reduced to about 10^{-5} mm. between each distillation. Both solvent and solution were stirred by placing small, glass enclosed, alnico magnets in the

sample holders and rotating a large horseshoe magnet slowly under the thermostat, as indicated in Fig. 1. Gradually decreasing values of the measured vapor pressure differences with successive readings, which were noted in early runs, were eventually traced to small amounts of permanent gases that were not removed by the vacuum distillations and came out of solution slowly, during a determination. This difficulty was overcome by adding 100 cc. of dead space to each side of the manometer at G and H, thus diluting the permanent gases to insignificant pressures. Corrections for the increased concentration of the solution, due to the volume of vapor, then became necessary. When the solvents used were water, ethyl alcohol, and acetone, a stopcock grease composed of 25% of lithium stearate dispersed in an oil with a viscosity of 3500 S.U.S. at 100° F. (3), was quite satisfactory. If, however, hydrocarbon solvents are required it would be necessary to use a glycerine–silica lubricant (6) or to substitute mercury cutoffs for the stopcocks.

For ordinary work, precise thermostatic control is not required. It is only necessary that the solution and solvent be kept at the same temperature; its absolute value is not important. The drift in the temperature of a liter beaker filled with water at about 2° C. below room temperature was found to be only a few tenths of a degree per hour, and this type of water bath was used to obtain most of the data reported in Table I. If a thermostat is used, the manometer D may be dispensed with, and the literature values for the vapor pressure of the pure solvent used.

Equilibrium is reached quickly, and measurements of the vapor pressure lowering may be taken at 15 to 20 min. intervals. Since the zero point of the manometer is a function of the room temperature, it is advisable to check it after each reading by turning the three way stopcock I to connect B and C. If this is done after the mercury has been adjusted to the etch at J no dilution of the sample takes place.

The preliminary results, which are presented in Table I, were sufficiently encouraging to warrant extending the work to smaller samples, and the apparatus was modified accordingly. The ballast bulbs H and G were sealed off to reduce the volume, and sample holders of the form shown in large scale in Fig. 1-A were prepared. These were made by sealing about 5 cm. of 2 mm. I.D. tubing to $\frac{12}{30}$ S.T. ground glass joints. Stirring of solvent and solution was accomplished by placing a piece of a glass enclosed iron nail, about 1 cm. long and 0.8 mm. diameter, in the tubes and passing a small magnet vertically past the sample holders about 200 times per minute. This caused the stirrers to execute a "hula dance", which produced good agitation.

The samples of solute were weighed directly into the sample holders on a microbalance and after these were placed in position, the whole apparatus was evacuated to a pressure of 10^{-5} mm. Weighed samples of solvent (about 20 to 40 mgm.) were then attached at the ground glass joints L and K and distilled into the system through the stopcocks. Dissolved permanent gases were removed by reducing the pressure while the solvent was held in the traps

with a refrigerant.   It was relatively easy to remove the gases from the small quantities of solvent used, and two cycles of evaporating and condensing were usually enough.   The solution was finally prepared by condensing the solvent into the sample holder and stirring.   For this work the temperature of the thermostat was held close to 20° C. and was sufficiently constant that no variation could be observed on a Beckmann thermometer over periods of several hours.   The volume of the dead space on the solution side of the manometer was determined by expanding a known volume of air at a pre-determined pressure into it and noting the resulting pressure.   This made it possible to correct the solution concentration for the solvent in the vapor phase.

An alternative method of introducing the solvent, which produced good results, is as follows.   The solvent is boiled in a flask fitted with a stopcock and ground glass joint until dissolved gases are removed.   The stopcock is then closed and the flask attached to the apparatus, leaving the solvent stored, air-free, in the liquid state.   Known amounts may be admitted to the evacuated system through K and L, by measuring the pressure of the solvent while it is in the vapor phase, in a calibrated volume.   This scheme requires some additional apparatus that is not indicated in Fig. 1.

The vapor pressure differences between solvents and solutions were measured in the usual way with the differential manometer, and the molecular weights of the solutes calculated from Raoult's law.

Results and Discussion

The experimental results are presented in Tables I and II.   Individual values of consecutive measurements are given to indicate the spread obtained in the data.

Apparently the micromethod is capable of as high a degree of precision as can be obtained when larger quantities are used.   This is not too surprising since the chief source of error lies in the failure to remove the last traces of dissolved gases in the solvent, and it is easier to remove these from 30 than from 500 mgm.   Also, drafts in the room can also cause brief pressure changes in the ballast bulbs required for the larger samples and lead to errors that do not occur with the micro samples.

With the last three examples cited in Table II the solvent was measured and introduced in the vapor state.   When such small samples as this are used, some added precautions are necessary.   In addition to reducing the pressure within the apparatus to a "click" vacuum on a McLeod gauge prior to intro-ducing the solvent, it is desirable to expose the inside of the apparatus and the solute sample to the solvent vapor at a pressure somewhat less than the vapor pressure of the solvent, followed by reducing the pressure to a "click" vacuum once again before the solution is prepared.   This treatment removes adsorbed air and water vapor, which would give trouble in the subsequent determination. Another precaution that was found necessary when absolute alcohol was used as a solvent arose from the fact that the alcohol was only about 99% C_2H_5OH.

TABLE I

MOLECULAR WEIGHT DETERMINATIONS

Solute	Amount used, mgm.	Solvent	Thermostat	Molecular weight	
				Theoretical	Experimental
Mannitol	14	Water	Uncontrolled	182	181 181 184 189
					Av. 184
Triphenyl phosphate	9	Absolute alcohol	Uncontrolled	333	328 326 330
					Av. 328
Stearic acid	8	Absolute alcohol	Uncontrolled	284	285 291 292
					Av. 289
Triphenyl phosphate	3	Acetone	Automatic	333	328 321 340 350
					Av. 335
Stearic acid	2	Acetone	Automatic	284	280 291 296 296
					Av. 291

To reduce the slight fractionation that occurred on the solvent side of the manometer, where the dead space was larger, to insignificant proportions, it was necessary to use at least as much solvent as the solution contained.

In the last example in Table II the value of $P - P_0$ was less than 0.02 mm. and the total spread of all four readings was only 0.0011 mm. This indicates the precision that can be obtained with the manometer.

From the formula given, relating the molecular weight to vapor pressure lowering, it is obvious that for a given weight concentration of solute $P - P_0$ will be proportional to the product of P and M. Thus if it were possible to use both water and ethyl ether as solvents for a determination at 20° C., only about 0.01 of the weight concentration used with the water would be required for the ether solution to give the same $P - P_0$. This point is illustrated in Table I, where decreasing quantities of solute are used in passing from the solvents with low to those of higher vapor pressures. However, since other sources of error such as the increased effect of fluctuations in room temperature

TABLE II

MOLECULAR WEIGHTS FROM MICROSAMPLES

Solute	Amount used, mgm.	Solvent	Molecular weight	
			Theoretical	Experimental
Mannitol	1.207	Water	182	182 181 181 183 Av. 182
Palmitic acid	0.882	Absolute alcohol	256	254 261 258 Av. 258
Triphenyl phosphate	0.818	Absolute alcohol	333	350 347 338 Av. 345
Triphenyl phosphate	0.218	Absolute alcohol	333	324 320 326 Av. 324
Yohimbine	0.137	Absolute alcohol	354	410 350 365 357 357 Av. 368
Yohimbine	0.095	Absolute alcohol	354	355 344 367 355 Av. 355

and higher temperature coefficients of vapor pressure become more important as the vapor pressure increases, it is probably preferable to keep the molecular concentration of solute about the same for the two solvents and use a less sensitive manometer than has been used here.

Another important consideration is the chemical stability of the solvent. Water and alcohol are very good in this respect but acetone must be used with care.   Reasonably good results may be obtained with it, as Table I shows, if the vapor pressures are measured as soon as possible after the solutions are made up, but very real changes in vapor pressure appear to take place if the acetone solutions are allowed to stand.   This is probably due to photo-chemical reactions and the effect may be exaggerated with the dilute solutions and highly sensitive differential pressure measurements used here.

The method as described should be of considerable use especially where the amount of material available is limited. While setting up the apparatus initially may be somewhat complicated, once built, the assembly is permanent, and a determination may be made in two to three hours. The samples are, of course, completely recoverable.

Work is now in progress to extend the molecular weight range to include polymers.

Acknowledgment

The many helpful discussions that were held with Dr. L. Marion during the progress of this work, and the technical assistance of Mr. J. F. Eagen, who made the micro weighings referred to in the text, are gratefully acknowledged.

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SOME ANOMALOUS REACTIONS OF
PHENYLMAGNESIUM CHLORIDE[1]

By Richard H. F. Manske and Archie E. Ledingham

Abstract

When phenylmagnesium chloride is prepared from magnesium in chlorobenzene without the aid of another solvent, there is formed not only the expected diphenyl in addition to the phenylmagnesium chloride but also tractable amounts of xenyl- and terphenyl-magnesium chlorides. The presence of these substances for the formation of which a mechanism is not suggested was proved by the isolation of *p*-xenylethyl alcohol, *p*-terphenylethyl alcohol, and *p*-phenylbenzoic acid when the Grignard compounds were treated with appropriate reagents.

In the course of a study of the preparation of phenylmagnesium chloride in chlorobenzene without the aid of another solvent it was observed that products other than diphenyl and the desired Grignard compound were obtained. When the mixture was treated with ethylene oxide there was obtained a fair yield of phenylethyl alcohol and a higher boiling fraction from which it was possible to isolate terphenyl and *p*-xenylethyl alcohol. Kharasch and Fields (2) have drawn attention to a free radical mechanism which accounts for the formation of the higher condensed hydrocarbons such as terphenyl, quadriphenyl, etc. These authors however do not mention the formation of *p*-xenylmagnesium halides and their homologues. That such occur under the present experimental conditions was proved by the isolation not only of *p*-xenylethyl alcohol but also of *p*-terphenylethyl alcohol. Furthermore, when the Grignard mixture was carbonated the resulting acids consisted of a mixture of benzoic acid and *p*-phenylbenzoic acid.

Owing to the pressure of other work the present results are submitted without attempts to propose a mechanism. For the greater part, the magnesium used in these experiments was a sample of the distilled metal which was kindly placed at our disposal by Dr. L. M. Pidgeon, The University, Toronto, Ont. Experiments in which the magnesium had been alloyed with cobalt or with copper to increase its activity did not materially affect the results.

Experimental

Phenylmagnesium Chloride

Fresh magnesium borings (72 gm.) and monochlorobenzene (1000 gm.) were heated to boiling in a three liter flask fitted with a mercury seal stirrer and a reflux condenser fitted with a drying tube. Dissolution of the magnesium usually began after about 10 min. of boiling. In some experiments it was necessary to start the reaction by the addition of a crystal of iodine. With fine borings obtained by the use of a sharp drill, the magnesium had dissolved virtually completely in 10 hr.

Phenylethyl Alcohol

A solution of ethylene oxide (99 gm.) dissolved in chlorobenzene (400 gm.) was added to the Grignard reagent prepared as above at such a rate that the temperature did not exceed 35° C. A cooling bath of iced water was sufficient to maintain this temperature if the addition time was of the order of one hour. If the cooling is not maintained, a second more pronounced exothermal reaction takes place and the mixture sets to a firm gel which cannot be stirred. When all the ethylene oxide had been added the cooling bath was removed. A spontaneous reaction then ensued during which the temperature rose to 80° C. To complete the rearrangement the flask was immersed in a boiling water bath for one hour. After cooling to room temperature the resultant firm gel was decomposed with dilute sulphuric acid and the mixture filtered to facilitate subsequent separation of the liquid layers. The chlorobenzene solution was washed with water, the solvent removed under reduced pressure, and the residue fractionated *in vacuo*. The main fraction distilled at 100° to 120° C. (12 mm.) and consisted chiefly of phenylethyl alcohol, contaminated with some diphenyl with which it forms a constant boiling mixture. The yield was 185 gm.

Xenylethyl Alcohol and Terphenyl

The residue from the phenylethyl alcohol was subjected to further fractionation *in vacuo* and the fraction boiling at 160° to 180° C. (2 mm.) fractionally crystallized from benzene–hexane. From 50 gm. of such a fraction a small amount of a sparingly soluble material separated which when recrystallized several times, melted sharply at 213° C.* Terphenyl is stated to melt at 209° C. uncorrected (1) and the analytical figures indicate that the compound was terphenyl. Calc. for $C_{18}H_{14}$: C, 93.91; H, 6.09%. Found: C, 93.97; H, 6.22%.

The mother liquors from the terphenyl on concentrating and chilling, and repeated recrystallization from benzene–hexane, yielded some *p*-xenylethyl alcohol melting sharply at 94° C. (4). Calc. for $C_{14}H_{14}O$: C, 84.85; H, 7.07%. Found: C, 84.60, 84.61; H, 6.73, 6.87%.

When the *p*-xenylethyl alcohol was treated under anhydrous conditions with phenylisocyanate it yielded the corresponding *urethane* which when recrystallized from benzene–hexane consisted of colorless needles melting at 103° C. Calc. for $C_{21}H_{18}O_2N$: N, 4.43%. Found: N, 4.34%.

Terphenylethyl Alcohol

A higher boiling fraction (180° to 220° C. (2 mm.)) from the phenylethyl alcohol preparation solidified partly on standing. When the separated solid was recrystallized several times from benzene it was obtained in colorless plates melting at 224° to 225° C. That it is *p*-terphenylethyl alcohol is confirmed

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* *All melting points are corrected.*

by its analysis, although there was insufficient for the preparation of a derivative. Calc. for $C_{20}H_{18}O$: C, 87.59; H, 6.57%. Found: C, 87.27, 87.39; H, 6.22, 6.35%.

Benzoic Acid and Phenyl Homologues

The Grignard reagent as prepared above was diluted with sufficient dry ether to render the mixture mobile enough to pour on to an excess of solid carbon dioxide. When the excess carbon dioxide had evaporated, the mixture was acidified with dilute hydrochloric acid and filtered. The washed organic layer was then extracted with aqueous sodium carbonate and the acids regenerated from the aqueous extract.

The product thus obtained consisted substantially of benzoic acid but there was present a small portion only very sparingly soluble even in boiling water. This portion was collected from several runs and esterified with methanol and sulphuric acid, and the ester fractionated *in vacuo*. The low boiling fraction (70° to 100° C. (2 mm.)) consisted largely of methyl benzoate.

A second fraction collected at 150° to 170° C. (2 mm.) solidified for the greater part and when recrystallized from methanol consisted of large colorless plates melting at 117° C. (3). This is methyl *p*-phenylbenzoate. The recrystallized acid obtained by hydrolysis of the ester melted at 227° C. (3).

From a higher boiling fraction (170° to 240° C. (2 mm.)) a small amount of a compound melting at 225° to 226° C. was obtained. It consisted of pale greenish yellow fluorescent plates when recrystallized from methanol–benzene. It may consist substantially of a methyl terphenyl carboxylate. Calc. for $C_{20}H_{16}O_2$: C, 83.33; H, 5.55. Found: C, 82.08, 82.44; H, 5.76, 5.90%.

Diphenyl and Terphenyl

The alkali insoluble portion from the preparation of the benzoic acid was distilled *in vacuo* and the fraction boiling at 100° to 120° C. (5 mm.) after being recrystallized from methanol melted at 69° C. either alone or in admixture with diphenyl.

A second fraction collected at 160° to 220° C. (5 mm.) when recrystallized from benzene–hexane melted at 213° C. either alone or in admixture with a specimen of terphenyl obtained as above.

A third fraction which sublimed at 200° to 220° C. (1 mm.) when recrystallized from benzene was obtained in colorless plates melting at 300° to 305° C. The amount was insufficient for analysis but it probably consisted substantially of quaterphenyl for which Ullmann and Myer (5) give a melting point of 317° C.

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THE SYNTHESIS OF SOME ISOQUINOLINES[1]

By Richard H. F. Manske and Marshall Kulka

Abstract

A number of new isoquinolines substituted in the benzene nucleus have been prepared. The substituents include hydrazino-, chloro-, nitro-, and some combinations of these.

In connection with another problem a number of hydrazinoisoquinolines were required. Two of the necessary aminoisoquinolines (5- and 7-) are already known and served as the basis for orienting a number of new compounds.

Attempts to ring close the Schiff base (I) with sulphuric acid of several concentrations at temperatures below 100° C. led to regeneration of *m*-chlorobenzaldehyde, and fluosulphonic acid caused polymer formation. However, a mixture of sulphuric acid and phosphorus pentoxide at 160° C. (6) yielded a mixture of 5- (II) and 7-chloroisoquinoline (III), the components of which could be separated by crystallization of the bases from hexane or of the perchlorates from dilute perchloric acid. The orientation of the chlorocompounds was established by comparison with the 5- and 7-chloroisoquinolines obtained via the Sandmeyer reaction from the 5- (1, 4, 5, 6) and 7-aminoisoquinolines (5), respectively.

Nitration of the 5- and 7-chloroisoquinolines yielded 5-chloro-8-nitro- (V) and 7-chloro-8-nitroisoquinolines (VI) respectively, which, when heated with ethanolic ammonia at 150° C. gave rise to the known corresponding 5-amino-8-nitro- (VIII) (3) and 7-amino-8-nitroisoquinolines (IX). An attempt to convert the latter (IX) into 8-nitroisoquinoline by treating the diazonium salt with hypophosphorous acid yielded only 8-chloroisoquinoline (X) (3). The labilization of a nitro-group by a diazonium group, to the extent that the former is replaced by chlorine in the presence of hydrochloric acid, is not new (3). When the diazonium salt of IX was treated with stannous chloride in hydrochloric acid it yielded 7-hydrazino-8-chloroisoquinoline (XI).

Direct chlorination of 7-acetylaminoisoquinoline gave erratic results and only in one experiment was it possible to isolate a homogeneous substance which upon deacetylation and elimination of the amino-group yielded 8-chloroisoquinoline. That the chlorine entered the 8-position is further confirmed by the observation that the hydrazinoisoquinoline prepared from it was identical with XI obtained as above. Nitration of 7-acetylaminoisoquinoline yielded only tarry products.

An attempt to prepare 7-amino-8-chloroisoquinoline from 7-hydroxy-8-chloroisoquinoline by the Bucherer reaction yielded chiefly 7-aminoisoquino-

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line, the halogen having been eliminated. The necessary hydroxy-chloro compound was prepared by ring closure of the Schiff base from 2-chloro-3-hydroxybenzaldehyde and aminoacetal.
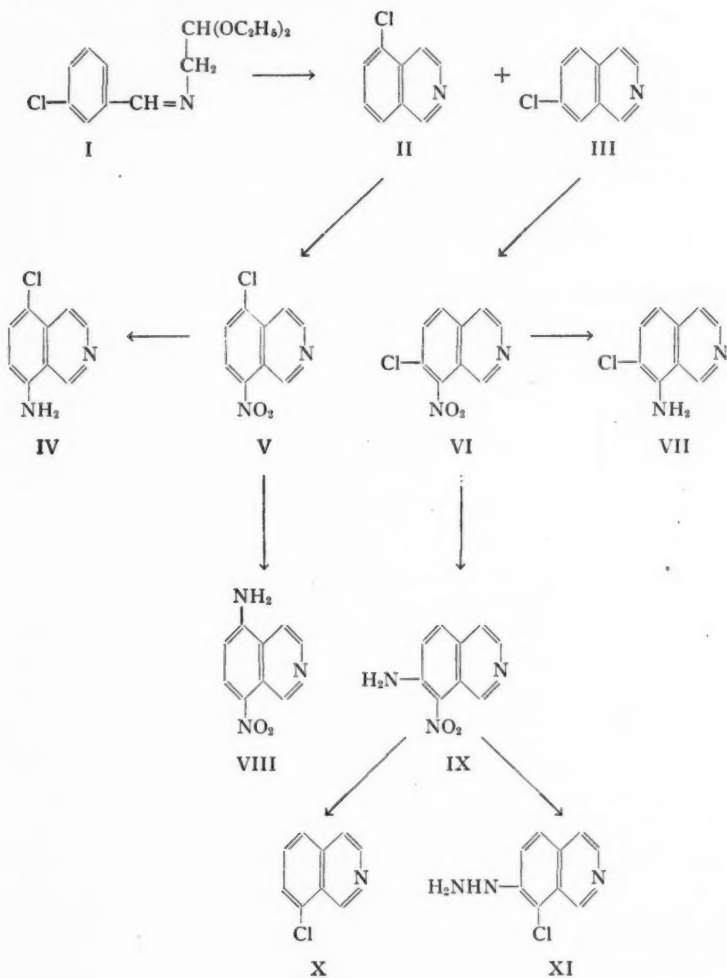
Experimental

7-Aminoisoquinoline

This was prepared from 7-hydroxyisoquinoline according to the method of Robinson (5). In the preparation of 7-hydroxyisoquinoline (7) better yields were obtained when the Schiff base of *m*-hydroxybenzaldehyde and amino-acetal was purified before cyclization. Acetylation with acetic anhydride in

acetic acid yielded 7-acetylaminoisoquinoline; m.p. 147° to 148° C.,* from benzene.   Calc. for $C_{11}H_{10}N_2O$: C, 70.98; H, 5.38; N, 15.06%.   Found: C, 70.72, 70.92; H, 5.44, 5.42; N, 14.64%.

The hydrate melts at 103° to 104° C.

5- and 7-Hydrazinoisoquinoline

A solution of 5-aminoisoquinoline (4) (14.4 gm.) in concentrated hydrochloric acid (50 cc.) and water (75 cc.) was diazotized with a solution of sodium nitrite (6.9 gm.) in water (50 cc.), the temperature being kept below 0° C.   The diazonium salt solution was then added to a cold solution of stannous chloride dihydrate (50 gm.) in concentrated hydrochloric acid (75 cc.) with stirring over a period of about 15 min. the temperature being maintained at 10° C. by cooling.   Then the reaction mixture was allowed to stand for two hours, the yellow precipitate filtered, and the filtrate concentrated to *ca.* 50 cc. under reduced pressure, and cooled.   The yellow precipitate was again filtered.   The combined precipitates were dissolved in 500 cc. of hot water and the solution saturated with hydrogen sulphide.   The tin sulphide was filtered off, washed with water, the combined filtrate and washings concentrated to *ca.* 100 cc. under reduced pressure, and the concentrate basified with ammonium hydroxide.   The precipitated 5-hydrazinoisoquinoline was filtered, washed, and crystallized from ethanol; white needles, m.p. 165° to 167° C.; yield, 8.1 gm. or 51%.   Calc. for $C_9H_9N_3$: C, 67.92; H, 5.65; N, 26.40%.   Found: C, 67.67, 67.87; H, 5.59, 5.77; N, 26.01, 25.96%.

7-Hydrazinoisoquinoline was prepared similarly from 7-aminoisoquinoline; orange prisms from benzene, m.p. 158° to 160° C.; yield, 50%.   Calc. for $C_9H_9N_3$: C, 67.92; H, 5.66; N, 26.40%.   Found: C, 67.90, 67.86; H, 5.87, 6.06; N, 25.80, 25.81%.

5- (II) and 7-Chloroisoquinolines (III)

(a) From the Aminoisoquinolines

A solution of 5-aminoisoquinoline (4.8 gm.) in concentrated hydrochloric acid (10 cc.) and water (25 cc.) was diazotized with a solution of sodium nitrite (2.3 gm.) in water (15 cc.) at 0° C.   This was then added to a solution of cuprous chloride (4.0 gm.) in concentrated hydrochloric acid (40 cc.) previously warmed to *ca.* 75° C.   The resulting solution was allowed to stand at room temperature overnight and then basified with sodium hydroxide and steam distilled.   The solid material was separated from the steam distillate and dried; yield, 3.3 gm. or 60%; crystallized from petroleum ether (b.p. 30° to 50° C.), white needles, m.p. 73° to 74° C.   Calc. for C_9H_6NCl: C, 66.05; H, 3.67; N, 8.56%.   Found: C, 66.31, 66.38; H, 3.72, 3.83; N, 8.56; 8.16%.

7-Chloroisoquinoline (III) was prepared similarly; m.p. 44° to 45° C., from petroleum ether; literature (5), 45° C.   Perchlorate, white needlelike crystals

* *All melting points are corrected.*

from methanol – ethyl acetate; m.p. 163° to 164° C.   Calc. for $C_9H_7NCl_2O_4$: C, 40.95; H, 2.65%.   Found: C, 41.02, 41.20; H, 3.09, 3.15%.

(b) From m-Chlorobenzaldehyde

A solution of *m*-chlorobenzaldehyde (2) (25 gm.) and aminoacetal (25 gm.) was heated on the steam bath for one-half hour and then distilled.   The Schiff base was an almost colorless liquid distilling at 170° C. (11 mm.); yield, 42 gm. or 86%.   Calc. for $C_{13}H_{18}NO_2Cl$: C, 61.04; H, 7.05%.   Found: C, 60.87, 60.92; H, 7.16, 7.01%.

The Schiff base (50 gm.) was added over a period of 15 min. to stirred concentrated sulphuric acid (250 cc.), the temperature being kept at 5° C. by cooling.   The resulting solution was then added, over a period of five minutes, to a stirred mixture of concentrated sulphuric acid (25 cc.) and phosphorus pentoxide (75 gm.) heated at 150° to 160° C.   The dark solution was heated for 25 min. longer, cooled, diluted with water, and steam distilled in order to remove *m*-chlorobenzaldehyde (3.5 gm.), a product of hydrolysis.   The acid solution was basified with sodium hydroxide and steam distilled, yielding an oily mixture of the chloroisoquinolines (8.0 gm. or 25%) which solidified on cooling.   Crystallization from petroleum ether (b.p. 30° to 50° C.) yielded 4.2 gm. of 5-chloroisoquinoline; m.p. 72° to 73° C.   The filtrate was taken to dryness, the residue dissolved in 15 cc. of warm 30% perchloric acid, and the solution cooled, yielding 1.2 gm. of the needlelike crystals of the perchlorate of 7-chloroisoquinoline, m.p. 162° to 163° C.   The perchloric acid filtrate was basified, the precipitated oil extracted with ether, the ether removed and the residue subjected to further alternate crystallizations from petroleum ether and 30% perchloric acid.   In this way there was obtained 5.3 gm. of 5-chloroisoquinoline and 1.6 gm. of the 7-chloroisoquinoline perchlorate.

In a smaller scale run (5 gm. of the Schiff base) the yield of the mixed chloroisoquinolines was 38% and the two components were present in about equal quantities.

5- (V) and 7-Chloro-8-nitroisoquinolines (VI)

To a solution of 5-chloroisoquinoline (16.5 gm.) in concentrated sulphuric acid (120 cc.) was added with stirring a solution of potassium nitrate (12 gm.) in concentrated sulphuric acid (100 cc.) over a period of about five minutes. The temperature was maintained at 20° to 25° C.   After allowing the reaction mixture to stand at room temperature for one hour, it was poured on ice and basified with ammonium hydroxide.   The yellow precipitate was filtered, washed with water, air-dried, and crystallized from methanol or benzene; light-yellow needles, m.p. 134° to 135° C.; yield, 17.8 gm. or 87%.   Calc. for $C_9H_5N_2O_2Cl$: C, 51.78; H, 2.40; N, 13.43%.   Found: C, 51.97, 52.01; H, 2.63, 2.76; N, 13.74, 13.75%.

7-Chloroisoquinoline was nitrated in a similar manner, giving an 85% yield of *7-chloro-8-nitroisoquinoline* (VI); light-yellow needles from methanol, m.p. 146° to 147° C.   Calc. for $C_9H_5N_2O_2Cl$: C, 51.78; H, 2.40; N, 13.43%. Found: C, 52.07, 52.10; H, 2.55, 2.63; N, 13.23, 13.12%.

5- (VIII) and 7-Amino-8-nitroisoquinolines (IX)

A solution of 5-chloro-8-nitroisoquinoline (V) (0.5 gm.) in absolute ethanol (75 cc.) containing ammonia (10 gm.) was heated at 150° C. in a 500 cc. hydrogenation bomb for 18 hr. The reaction mixture was taken to dryness and the residue crystallized from ethanol; orange needles, m.p. 265° to 268° C. (with decomposition). This was acetylated, yielding 5-acetylamino-8-nitro-isoquinoline; m.p. 225° to 227° C.; literature, 228° C. (3).

7-Chloro-8-nitroisoquinoline (VI) was aminated similarly, yielding *7-amino-8-nitroisoquinoline* (IX) (65%); orange needles, m.p. 246° to 247° C. from ethanol. Calc. for $C_9H_7N_3O_2$: C, 57.14; H, 3.70; N, 22.1%. Found: C, 56.80, 57.02; H, 3.76, 3.93; N, 22.96, 22.66%.

5- (IV) and 7-Chloro-8-aminoisoquinoline (VII)

A solution of 5-chloro-8-nitroisoquinoline (V) (17.8 gm.) in concentrated hydrochloric acid (100 cc.) was added to a cold solution of stannous chloride dihydrate (50 gm.) in concentrated hydrochloric acid (100 cc.). The reaction mixture was heated on the steam bath for one hour and then evaporated to dryness under reduced pressure. The residue was dissolved in hot water (1500 cc.) and the solution saturated with hydrogen sulphide. The tin sulphides were filtered and washed well with hot water in order to remove the sparingly soluble dihydrochloride. The combined filtrate and washings were basified with sodium hydroxide, the white voluminous precipitate, filtered and crystallized from benzene or ethyl acetate; white woolly needles, m.p. 204° to 205° C.; yield, 11.5 gm. or 75%. Calc. for $C_9H_7N_2Cl$: C, 60.50; H, 3.92; N, 15.70%. Found: C, 60.43, 60.32; H, 4.29, 4.22; N, 15.61%.

7-Chloro-8-aminoisoquinoline (VII) was prepared similarly from 7-chloro-8-nitroisoquinoline; almost white needles, from benzene, m.p. 171° to 172° C.; yield, 55%. Calc. for $C_9H_7N_2Cl$: C, 60.50; H, 3.92; N, 15.70%. Found: C, 60.56, 60.38; H, 4.28, 3.95; N, 15.73%.

Deamination of 7-Amino-8-nitroisoquinoline

To a solution of 7-amino-8-nitroisoquinoline (0.12 gm.) in concentrated hydrochloric acid (10 cc.) was added solid sodium nitrite (0.05 gm.) and the reaction mixture stirred at 0° C. for two hours. To this was added 30% hypophosphorous acid (2 cc.) and the solution allowed to stand at 0° C. for one hour and then at room temperature for 15 hr. The yellow solution was diluted with water, basified with sodium hydroxide, and steam distilled. The oily material in the steam distillate solidified on cooling; yield, 0.05 gm.; m.p. 54° to 55° C., mixed m.p. with an authentic sample of 8-chloroisoquino-line (3), no depression.

7-Hydrazino-8-chloroisoquinoline (XI)

7-Amino-8-nitroisoquinoline (IX) (1.1 gm.) was diazotized with solid sodium nitrite (0.38 gm.) as above and to this solution was added stannous chloride dihydrate (6.0 gm.) in concentrated hydrochloric acid (20 cc.) cooled

to 0° C.   The dark solution was allowed to stand at 8° C. overnight and then taken to dryness under reduced pressure.   The residue was dissolved in hot water (100 cc.) and the solution saturated with hydrogen sulphide.   The tin sulphides were filtered off and the filtrate basified with sodium hydroxide. The precipitated hydrazine was filtered and crystallized from benzene; golden-yellow needles, m.p. 176° to 178° C. (with decomposition); yield, 0.62 gm. or 56%.   Calc. for $C_9H_8N_3Cl$: C, 55.81; H, 4.13; N, 21.70%.   Found: C, 56.02, 56.02; H, 4.25, 4.11; N, 22.11%.

8-Hydrazino-5-chloroisoquinoline

This was prepared from 8-amino-5-chloroisoquinoline (IV) using the same method as that used for 7-hydrazino-8-chloroisoquinoline above; light-yellow needles, from benzene, m.p. 192° to 193° C. (with decomposition); yield, 80%. Calc. for $C_9H_8N_3Cl$: C, 55.81; H, 4.13; N, 21.70%.   Found: C, 55.86, 55.57; H, 4.36, 4.58; N, 21.66%.

7-Acetylamino-8-chloroisoquinoline

A solution of 7-aminoisoquinoline (1 gm.) in glacial acetic acid (10 cc.) and acetic anhydride (5 cc.) was heated on the steam bath for one-half hour and then cooled to 20° C.   Sodium acetate (1 gm.) was added and chlorine gas was passed in slowly with cooling until 0.7 gm. was absorbed.   The solvent was removed from the reaction mixture under reduced pressure, the residue dissolved in dilute hydrochloric acid, and the solution basified with ammonium hydroxide.   The precipitate was filtered, washed, dried, and crystallized twice from benzene; light-yellow prisms, m.p. 166° to 167° C.; yield, 0.7 gm. Calc. for $C_{11}H_9ON_2Cl$: C, 59.87; H, 4.08; N, 12.70%.   Found: C, 59.90, 59.97; H, 4.43, 3.62; N, 12.81, 12.99%.

In a few other experiments the chlorinated product was a mixture which could not be purified by crystallization from benzene.

7-Amino-8-chloroisoquinoline

7-Acetylamino-8-chloroisoquinoline (0.5 gm.) was dissolved in 20% hydrochloric acid (10 cc.) and the solution heated under reflux for one-half hour. The cooled solution was basified with dilute ammonium hydroxide and the precipitate, filtered, washed, and dried; yield 0.40 gm.; crystallized from benzene, fine white needles, m.p. 177° to 179° C.   Calc. for $C_9H_7N_2Cl$: C, 60.50; H, 3.92; N, 15.69%.   Found: C, 60.30, 60.15; H, 3.84, 3.99; N, 15.43%.   This compound when deaminated with hypophosphorous acid yielded a compound melting at 55° to 56° C. either alone or in admixture with 8-chloroisoquinoline (3).   Also, when diazotized and then reduced with stannous chloride it yielded golden-yellow needles which melted at 173° to 174° C. (with decomposition) alone or in admixture with 7-hydrazino-8-chloroisoquinoline (XI).

7-Hydroxy-8-chloroisoquinoline

A solution of 2-chloro-3-hydroxybenzaldehyde (2) (15 gm.) and aminoacetal (15 gm.) was heated on the steam bath for one-half hour, and then the water of reaction removed by alternate addition and distillation of benzene.   To the cooled, well dried, dark brown residual liquid was added with stirring and cooling 76% sulphuric acid (100 cc.) previously cooled to 0° C.   After stirring the reaction mixture for four hours at 2° to 5° C., it was allowed to stand for 40 hr. at 8° C. and 30 hr. at room temperature.   The resulting thin slurry was dissolved by addition of water, basified with ammonium hydroxide, and buffered with sodium carbonate.   The precipitated brown solid was filtered and sublimed at 175° C. (1 mm.).   The yield of white sublimate was 12.0 gm. or 64%; crystallized from methanol, white needles, m.p. 230° to 231° C. Calc. for C_9H_6NOCl: C, 60.16; H, 3.34; N, 7.80%.   Found: C, 59.87, 60.17; H, 3.67, 3.53; N, 7.37%.

The Bucherer Reaction with 7-Hydroxy-8-chloroisoquinoline

Into a suspension of 7-hydroxy-8-chloroisoquinoline (0.5 gm.), water (8 cc.), and concentrated ammonium hydroxide (3 cc.) was passed sulphur dioxide until 2.5 gm. was absorbed.   To the resulting solution, concentrated ammonium hydroxide (20 cc.) was added and the reaction mixture heated at 120° C. for 16 hr. in a hydrogenation bomb.   The amber solution was taken to dryness under reduced pressure, and the residue heated with concentrated hydrochloric acid in order to drive off most of the sulphur dioxide and then basified with sodium hydroxide and cooled.   The precipitated solid (0.07 gm.) when crystallized from benzene melted at 203° to 204° C. alone or in admixture with 7-aminoisoquinoline.

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REFRACTIVE INDEX OF HYDROGEN PEROXIDE SOLUTIONS. A REVISION[1]

By Paul A. Giguère and Pierre Geoffrion[2]

Abstract

Values for the refractive index of aqueous solutions of hydrogen peroxide reported some years ago by the senior author have been found in error by more than the estimated accuracy of measurements. The error is proportional to the concentration of the solutions and amounts to about 5×10^{-4} for the pure peroxide. More accurate data have now been obtained by using an instrument of higher precision and by refining the analytical method. In addition, some anhydrous hydrogen peroxide has been prepared; its refractive index at 25° C. was $1.4067_2 \pm 0.0001$ with an average temperature coefficient of 3.4×10^{-5} per degree.

A few years ago the refractive index of hydrogen peroxide solutions was determined in this laboratory (2) in order to provide a convenient method of instrumental analysis. The measurements, made with a Pulfrich refractometer, covered the whole concentration range in steps of 10% at four different temperatures; the solutions were analyzed by the usual titration with potassium permanganate. At that time the results were believed correct to about 1 part in 1000. However, a series of measurements made recently in another laboratory (5) have revealed more serious discrepancies. A review of the question has led to the following conclusions. The error could be traced either to the instrument or to the analysis of solutions or both. The refractometer itself could not be suspected since it was repeatedly checked with distilled water throughout the investigation. On the other hand the temperature was not controlled with enough accuracy, as has been discovered since. The practice of not using the metal water jacket in order to avoid decomposition of the peroxide resulted in a liquid sample that was slightly warmer or cooler than the prism, depending on whether the measurements were made below or above room temperature. Since the temperature coefficient of the refractivity of hydrogen peroxide is three times as large as that of water the ensuing error increased with the concentration of solutions. Still this could not very likely be the only source of error as it would imply deviations of the order of 2° C.

The chemical analysis is equally open to question; besides it is not so easily checked against an absolute method. (The results of Huckaba and Keyes (3) were not yet available when the present investigation was completed.) Provided the reaction is quantitative, volumetric methods, when properly carried out, are capable of an accuracy of the order of 1 part in 1000. This is entirely satisfactory for the more dilute solutions, but as the concentration

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of hydrogen peroxide is increased the absolute error increases accordingly. The same is true, indeed, of all determinations in which the major constituent is found directly. Titration with standard potassium permanganate was considered the most reliable; necessary precautions were always taken to prevent any appreciable decomposition of the peroxide due to formation of manganese dioxide. Standardization of the permanganate had been carried out according to the older method. This time the procedure recommended by Fowler and Bright (1) was followed. In fact the two methods were compared and a difference of the order of 0.15% was found.

Experimental

To minimize these errors the new measurements were made as follows. A Precision Abbé refractometer (Bausch and Lomb) being available in this laboratory, it was used in preference to the Pulfrich type because of its higher accuracy (2 to 3×10^{-5}). It was calibrated by means of a glass test piece supplied by the maker. The temperature was read to 0.1° C. on a thermometer placed next to the prisms; water was circulated from a thermostat controlled to $\pm 0.02°$ C. The cement holding the prisms had to be covered with Ceresin wax to prevent decomposition of hydrogen peroxide. A special feature of the instrument proved very useful for this work; an auxiliary lens is provided which can be moved into the telescope to give a view of the liquid layer between the prisms. Thus any appreciable decomposition could be detected from the presence of oxygen bubbles. Solutions that were too unstable were rejected. The determinations were made at 25° and 20° C. with the sodium light.

The solutions used were obtained by distillation of Becco's 90% hydrogen peroxide. In the lower concentration range it was necessary to dilute them with redistilled water; as a result they invariably showed a marked tendency to decompose, so that a trace of inhibitor (sodium stannate) had to be added. The stabilizing effect became noticeable only after a certain time (30 to 60 min.). Improvements in the analytical technique consisted mainly in using larger volumes of reagents, 90 to 95 cc. and a better standardization method. Duplicate analyses generally agreed among themselves to 1 part in 1000 or better. A special series of determinations were carried out to compare the accuracy of the permanganate and the thiosulphate methods. Samples of about 0.25 gm. of a 95% hydrogen peroxide solution in tiny vials were weighed to 0.01 mgm. on a microanalytical balance, using a set of certified weights. The vials were dropped into 500 cc. Erlenmeyer flasks containing 150 cc. of redistilled water and 3 cc. of sulphuric acid, and the titrations run immediately with freshly standardized reagents. The same burette, 100 cc. certified Normax, calibrated in 0.1 cc., was used for all titrations. The end points were estimated to ± 0.02 cc. after allowing reasonable time for draining.

The potassium permanganate solution, about $0.15\ N$, was standardized against certified sodium oxalate (National Bureau of Standards), and according to the above mentioned method (1).   The sodium thiosulphate was standardized against the permanganate for comparison purpose.   For peroxide analyses the acetic acid – ammonium molybdate method was followed with the latter reagent.   All operations were done the same day; the temperature of the various solutions did not vary by more than one degree.   As may be seen from the results of this test (Table I) the permanganate method is somewhat superior to the thiosulphate one.

TABLE I

ANALYSIS OF A CONCENTRATED HYDROGEN PEROXIDE SOLUTION

n_D (25° C.)	Permanganate method		Thiosulphate method	
	Normality	Wt. % H_2O_2	Normality	Wt. % H_2O_2
1.40213	0.1484$_5$	94.56$_7$	0.1497$_9$	94.62$_4$
1.40211	0.1486$_2$	94.53$_8$	0.1497$_9$	94.52
1.40211	0.1485$_5$	94.60$_4$	0.1498$_6$	94.58
1.40209	0.1486$_1$		0.1498$_5$	94.46$_8$
1.40212	0.1484$_8$		0.1497$_7$	
1.40211	0.1485$_6$			
1.40211	0.1485$_6$	94.57	0.1498$_1$	94.55
±0.00002	±0.0001	±0.03	±0.00005	±0.08

Since the accuracy of the chemical analysis was the limiting factor in the present work an attempt was made to prepare some pure anhydrous hydrogen peroxide.   Four liters of a 90% commercial solution was distilled under a pressure of 3 to 4 mm. of mercury in an all-glass apparatus connected with ground glass joints; the 3 ft. rectifying column was filled with glass rings. Thus a 99.8% solution was obtained (about one-half liter) which was then subjected to fractional crystallization after the technique outlined by Maass and Hatcher (4).   The progess of concentration was followed by measuring the refractive index with an immersion refractometer.   After the second operation this property did not change further; the observed value, 1.4067_2 at 25° C., is estimated to be correct to ±0.0001, considering the difficulty of removing last traces of water.   The average temperature coefficient between 15 and 25° C. was 3.4×10^{-5} per degree.

Results

The experimental data listed in Table II were plotted on a large graph, one division corresponding to 0.1% for composition and 0.0001 for refractive index.   All points fell closely on a smooth line, indicating that the measurements were self-consistent.   Values extrapolated from the first published data at 20° and 24° C. were also plotted on the same graph for comparison.   The

TABLE II

REFRACTIVE INDEX OF HYDROGEN PEROXIDE SOLUTIONS MEASURED AT 20 AND 25° C. WITH THE SODIUM-D LINE

%H$_2$O$_2$	n_D		%H$_2$O$_2$	n_D	
	25° C.	20° C.		25° C.	20° C.
0.00	1.3325$_1$	1.3329$_9$	60.6$_6$	1.3738$_9$	1.3750$_8$
10.1$_0$	1.3388$_1$	1.3394$_6$	70.1$_5$	1.3815$_1$	1.3828$_6$
19.9$_8$	1.3452$_1$	1.3460$_6$	79.8$_6$	1.3892$_7$	1.3907$_2$
30.1$_1$	1.3520$_3$	1.3529$_6$	92.3$_6$	1.3999$_8$	1.4015$_7$
40.0$_3$	1.3588$_5$	1.3598$_6$	96.2$_6$	1.4033$_3$	1.4049$_5$
50.1$_0$	1.3661$_1$	1.3672$_4$	99.3$_0$	1.4060$_7$	1.4077$_4$

two sets agree exactly up to about 40% where a slight deviation begins to be noticeable at that scale.   From that concentration up, the difference increases steadily, the present indices being lower.   The data of Table III, obtained

TABLE III

REFRACTIVE INDEX OF AQUEOUS SOLUTIONS OF HYDROGEN PEROXIDE AT 25° C.

H$_2$O$_2$ %		0.0	0.2	0.4	0.6	0.8	H$_2$O$_2$ %		0.0	0.2	0.4	0.6	0.8
0	1.3	325	326	327	328	329	33		540	541	543	544	546
1		331	333	334	335	336	34		547	548	550	551	553
2		338	339	340	341	343	35		554	555	557	558	560
3		344	345	347	348	349	36		561	562	564	565	567
4		350	352	353	354	355	37		568	569	571	572	574
5		357	358	359	360	362	38		575	576	578	579	581
6		363	364	365	367	368	39		582	583	585	586	588
7		369	370	372	373	374	40		589	590	592	593	595
8		376	377	378	379	381	41		596	598	599	600	602
9		382	383	384	386	387	42		603	605	606	608	609
10		388	389	391	392	393	43		611	612	613	615	616
11		395	396	397	398	400	44		618	619	621	622	623
12		401	402	404	405	406	45		625	626	628	629	631
13		407	409	410	411	412	46		632	633	635	636	638
14		414	415	416	418	419	47		639	641	642	643	645
15		420	421	423	424	425	48		646	648	649	651	652
16		427	428	429	430	432	49		653	655	656	658	659
17		433	434	436	437	438	50		661	662	663	665	666
18		439	441	442	443	444	51		668	669	671	672	674
19		446	447	448	450	451	52	1.3	675	677	678	680	681
20		452	453	455	457	458	53		683	684	686	687	688
21		459	460	462	463	464	54		690	691	693	694	696
22		466	467	468	470	471	55		698	699	700	702	703
23		472	474	475	476	478	56		705	706	707	709	711
24		479	480	482	483	484	57		712	713	715	716	718
25	1.3	486	487	488	490	491	58		719	721	722	724	725
26	1.3	492	494	495	496	498	59		727	728	730	731	733
27		499	500	502	503	504	60		734	736	737	739	740
28		506	507	508	510	511	61		742	744	745	747	748
29		512	514	515	516	518	62		750	752	753	755	756
30		519	520	522	523	525	63		758	760	761	763	764
31		526	527	529	530	532	64		766	768	769	771	772
32		533	534	536	537	539	65		774	776	777	779	780

TABLE III—*Concluded*

REFRACTIVE INDEX OF AQUEOUS SOLUTIONS OF HYDROGEN PEROXIDE AT 25° C.—*Concluded*

H_2O_2 %		0.0	0.2	0.4	0.6	0.8	H_2O_2 %		0.0	0.2	0.4	0.6	0.8
66		782	784	785	787	788	84		928	930	932	933	935
67		790	792	793	795	796	85		937	939	940	942	944
68		798	800	801	803	804	86		945	947	949	950	952
69		806	808	809	811	812	87		954	956	957	959	961
70		814	816	817	819	820	88		962	964	966	968	969
71		822	824	825	827	828	89		971	973	974	976	978
72		830	832	833	835	836	90		880	981	983	985	986
73		838	840	841	843	844	91		988	990	992	993	995
74		846	848	849	851	852	92		997	999	*000	*002	*004
75		854	856	857	859	860	93	1.4	006	007	009	011	013
76	1.3	862	864	865	867	868	94		014	016	018	020	021
77		870	872	873	875	876	95		023	025	027	028	030
78		878	880	881	883	884	96		032	034	035	037	039
79		886	888	889	891	892	97		041	042	044	046	048
80		894	896	897	899	901	98		049	051	053	055	056
81		903	904	906	908	909	99		058	060	062	063	065
82		911	913	915	916	918	100	1.4	067				
83		920	921	923	925	927							

from this large plot, show that extrapolation to 100% gives the same value as the direct determination with the immersion refractometer. The correction factors for temperature given in Table IV supersede those previously published.

TABLE IV

TEMPERATURE CORRECTIONS TO BE SUBTRACTED FROM THE PERCENTAGE OF HYDROGEN PEROXIDE (IN TABLE III)

Temp., °C.	Approximate concentration									
	10	20	30	40	50	60	70	80	90	100
20	0.9	1.2	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9
21	0.8	0.9	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.5
22	0.6	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1
23	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.8
24	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4

Refractive index measurements offer a most convenient method of determining the concentration of hydrogen peroxide solutions. Of the various types of instruments available the immersion refractometer is the best adapted to this purpose because of its high accuracy and good temperature control; in addition the solutions come in contact only with the glass prism. Two prisms (*A* and *B*) cover nearly all the concentration range. The Precision Abbé is also very accurate and easily thermostatically controlled. As mentioned above, some precautions are necessary to prevent decomposition of the peroxide on the cement; the chromium plated metal parts do not seem to

be affected by it. The Pulfrich refractometer is satisfactory for measurements around room temperature. Whatever the type of instrument used, the measurements must be made as soon as thermal equilibrium permits, to prevent appreciable change in composition of the solutions due either to evaporation or to the hygroscopic nature of the more concentrated ones (above 90%). Also, the solutions must be very stable, as any decomposition causes a blurred image of the dividing line owing to light scattering by gas bubbles.

Acknowledgment

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NOTES

The Cobalt Chloride Method for Determining Bound Water*

In the course of another investigation, a method was desired for determining the extent of solvation of methyl cellulose in aqueous solutions. In an article describing a promising method, Hatschek (4) stated: "When gelatin gels containing cobaltous chloride are allowed to dry at temperatures from 15° to 30°, they turn a pure blue before all the water which they can lose at the latter temperature has evaporated. The water still remaining in the gel must therefore be considered as water bound by the gelatin in the sense that it is no longer free to hydrate the cobaltous chloride". Hatschek made up disks of gelatin containing slightly over 20% of cobaltous chloride (on a dry basis) and visually followed the color change from red through purple to blue as they dried. The disks that had just turned blue were weighed and then the remaining moisture was removed by drying to constant weight at 100° C. The loss in weight was taken to represent the "bound water", which was determined to be 0.43 to 0.51 gm. per gm. dry gelatin for various gelatins. This agreed well with the value obtained by Moran (7) using a different method.

In the present investigation, the method of Hatschek (4) was applied to "gels" of methyl cellulose (Dow methocel, 15 cps.), using the suggested concentration of about 20% cobaltous chloride (Merck's reagent grade). A second experiment, in which a low concentration of cobaltous chloride was used, resulted in a much lower value for the "bound water". For this reason a series of measurements were made with varying concentrations of cobaltous chloride. The results are shown in Fig. 1, upper curve.

An extension of the measurements to gelatin showed that variations in the cobaltous chloride concentration affected the results in a similar manner. Dried Eastman pigskin gelatin was used. The results are given in the lower curve of Fig. 1. Points calculated from Hatschek's data (4) and those of Weidinger and Pelser (8) are included.

These latter investigators considered their values at different concentrations to be fairly constant and to agree with the value at the break point in the curve relating side chain spacings (from X-ray data) to amount of adsorbed water. This break occurred at about 0.45 gm. water per gm. dry gelatin. These authors also compared the adsorption isotherm of water on pure gelatin with that of water on gelatin containing about 2% cobaltous chloride. The isotherms were very similar up to a relative vapor pressure of slightly over 0.8, after which they began to separate and the color changed in the sample containing cobaltous chloride. This point corresponded to about 0.3 gm. water

per gm. dry gelatin. These isotherms were obtained by exposing the samples over sulphuric acid solutions in a desiccator, equilibrium being attained in about four weeks.
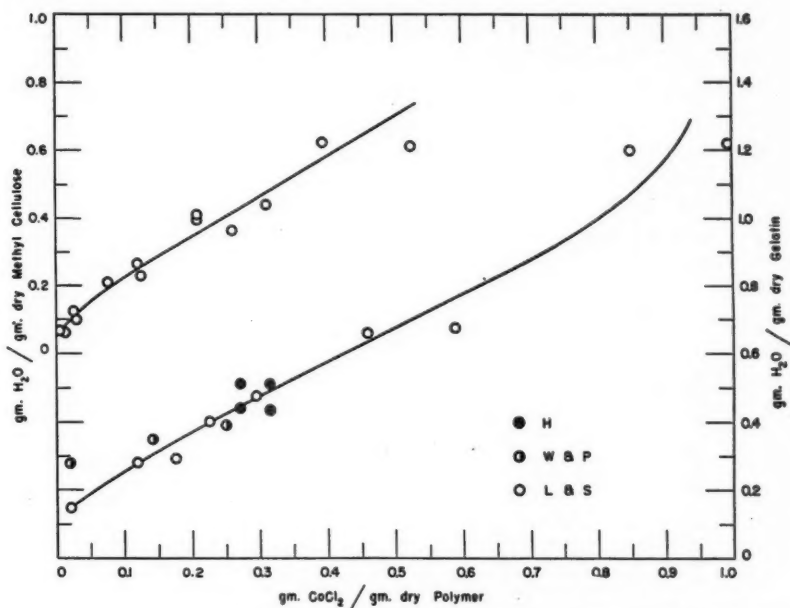

FIG. 1. *Water content of polymer at the color change (purple to blue) plotted against cobaltous chloride concentration. H—Hatschek (4), W and P—Weidinger and Pelser (8), L and S—this investigation.*

To check the significance of the point of separation of the isotherms, water–gelatin isotherms were obtained in this investigation, using the more accurate isopiestic method (5), in which equilibrium with sulphuric acid solutions was attainable in two days at 30° C. It was found that the isotherms were separated over their entire length, the amount of separation increasing with concentration of cobaltous chloride and with increasing relative vapor pressure. Concentrations of cobaltous chloride in the gelatin disks were 0, 0.3, 3.3, 12, 20, and 30%. At a relative pressure of 0.5 the weight of water adsorbed per gram dry gelatin for each of these concentrations was 0.15, 0.16, 0.17, 0.22, 0.30, and 0.51 gm., respectively, while at a relative pressure of 0.82 the corresponding values were 0.24, 0.25, 0.29, 0.46, 0.67, and 1.20 gm.

Since the color in the gelatin disks containing low concentrations of cobaltous chloride was quite faint, the color changes were difficult to judge accurately by eye. It was therefore decided to carry out some experiments on dilute solutions of cobaltous chloride in dry solvents to which water could be added and the color changes determined accurately by means of a colorimeter.

Dried reagent acetone and absolute ethyl alcohol were used as solvents. To 5 cc. of the blue solutions of cobaltous chloride, water was added from a graduated pipette in small increments, colorimeter readings being taken after each addition. A 6000 Å filter was used so that the light was strongly absorbed when the solutions were blue and a sharp increase in transmission occurred as soon as the red coloration began to appear. The weight of water per gram of dry solvent at this point is shown plotted against cobaltous chloride concentration in Fig. 2.
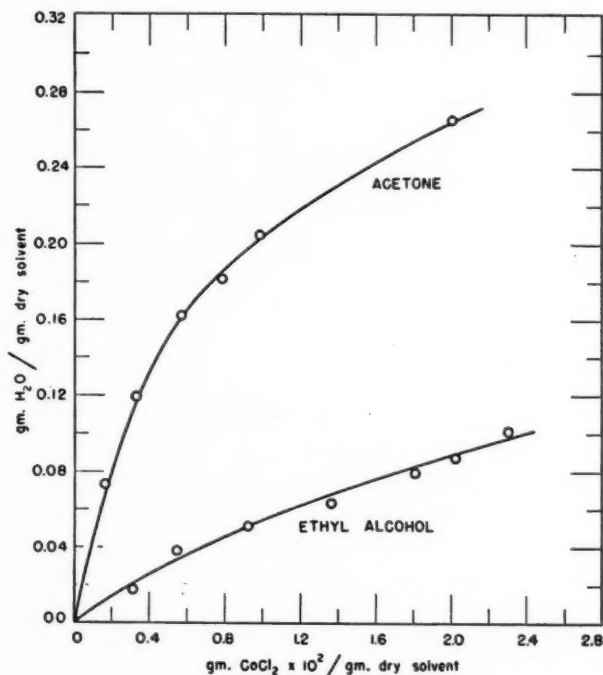

FIG. 2. *Water content of solvent at the color change plotted against cobaltous chloride concentration.*

The solvent – cobaltous chloride systems cannot be considered on exactly the same basis as the gelatin – cobaltous chloride system, since the cobaltous chloride is thought to be held intermicellarly in the latter (8). However, water which is strongly bound by the solvent would not be expected to cause a color change in the cobaltous chloride. The curves obtained are similar in type to those for gelatin and methyl cellulose in that they extrapolate to zero and rise rapidly with increasing cobaltous chloride concentration. There is no reason to believe that any one point on any of these curves gives a more meaningful value for the "bound water" than any other.

Although it is commonly thought that the color changes in cobaltous chloride are due to hydration, Donnan and Bassett (3) and Bassett and Croucher (1) have shown that hydration processes may be associated with the color changes though not themselves responsible for them and that, in some cases, water is not at all essential. To illustrate the latter point, solid anhydrous cobaltous chloride and solutions of cobaltous chloride in dry ethyl alcohol are blue at ordinary temperatures, but turn red at very low temperatures. According to these authors the blue color is due to the complex anions, $CoCl_4^{--}$ or $[CoCl_3, H_2O]^-$, and the red color is due to the cations, Co^{++}, $Co(H_2O)_6^{++}$, $Co(H_2O)_4^{++}$, $Co_2(H_2O)_{10}^{++++}$, or $Co_2(H_2O)_6^{++++}$, any of which may predominate, depending on concentration and temperature. Bassett and Croucher (1) suggest that a slight interchange of electronic linkages even in the solid crystals may introduce ions that impart the slight purplish tinge to the hexahydrate. Aqueous solutions of cobaltous chloride may be red, violet or blue, depending on concentration and temperature.

To further complicate the picture, it has been shown (2, 6) that alcoholates and acetonates of cobaltous chloride exist. It is rather likely, therefore, that some type of combination occurs between cobaltous chloride and the polar groups of gelatin and methyl cellulose. The extent of combination would probably be dependent on concentration.

In view of these facts, it is not surprising that the values of the "bound water" determined by the cobalt chloride method varied so markedly with concentration. It must be concluded that this method cannot give a meaningful value for bound water.

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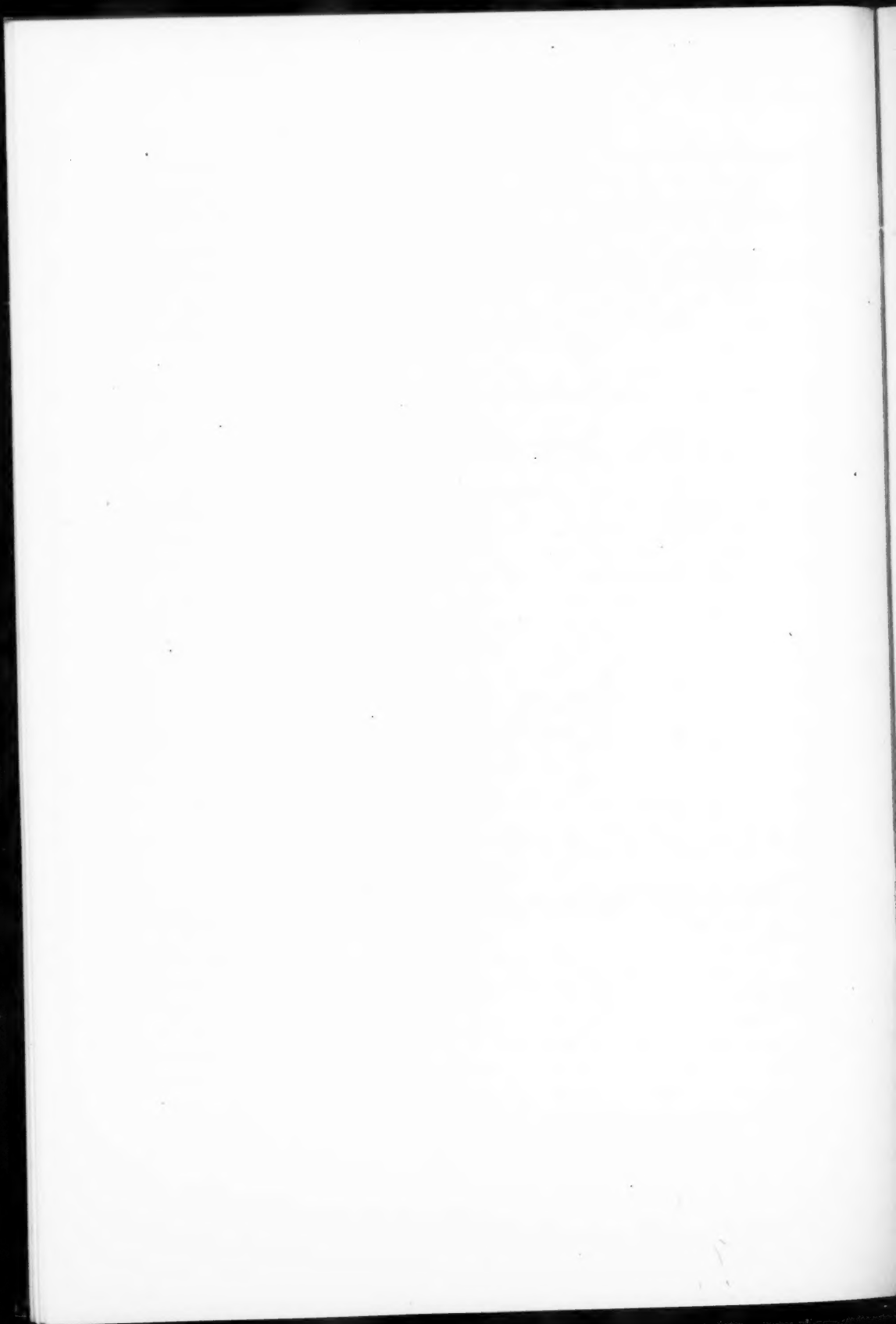
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